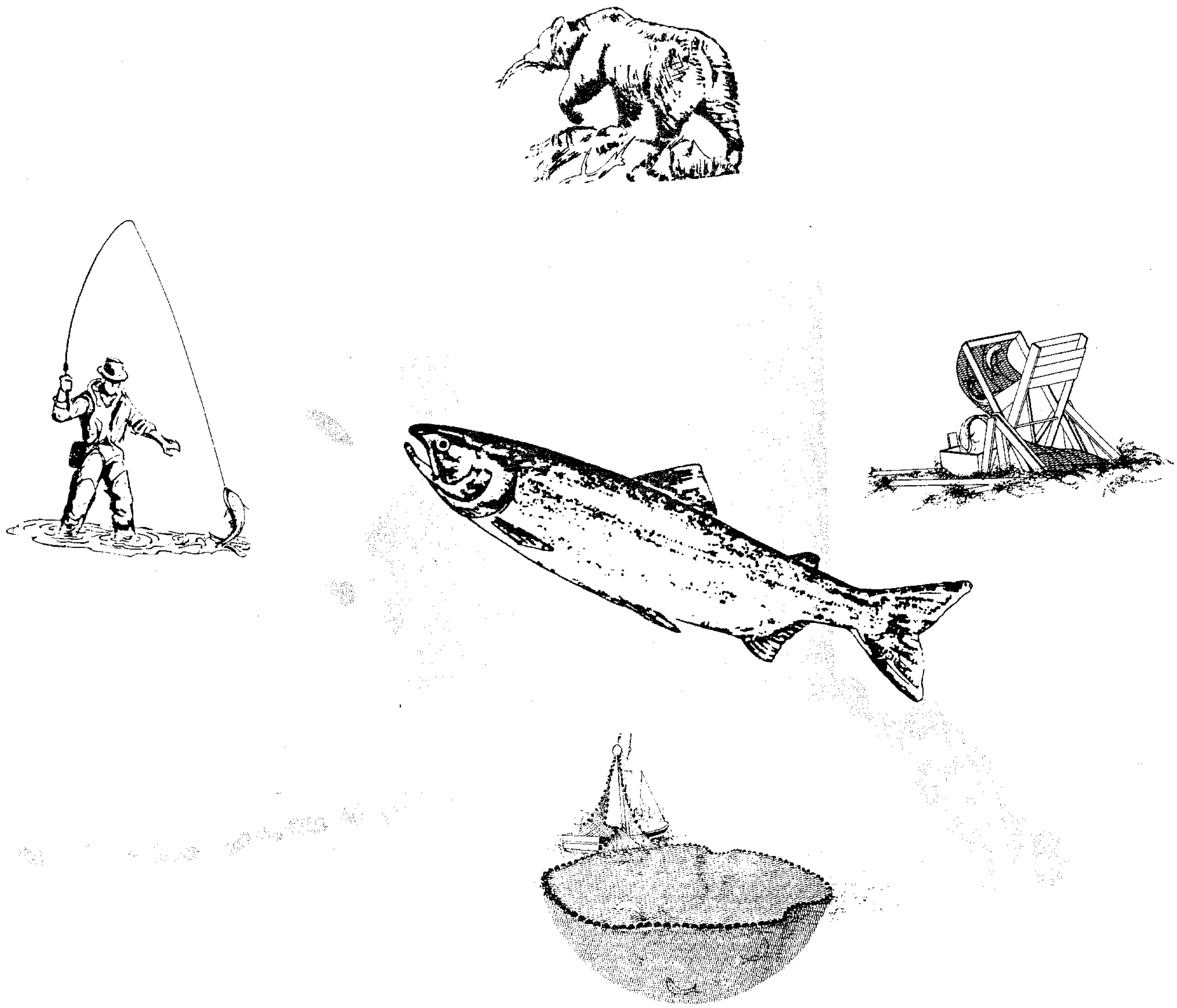
ABUNDANCE AND RUN TIMING OF ADULT SALMON IN THE EAST FORK ANDREAFSKY RIVER, YUKON DELTA NATIONAL WILDLIFE REFUGE, ALASKA, 1994

Alaska Fisheries Progress Report Number 95-5



June 1995

Region 7
U.S. Fish and Wildlife Service • Department of the Interior

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Table of Contents

Page

List of Tables

Table *Page*

List of Figures

Figure

List of Appendices

Appendix

Abundance and Run Timing of Adult Salmon in the East Fork Andreafsky River, Yukon Delta National Wildlife Refuge, Alaska, 1994

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Abstract.—From June 29 to August 1, 1994, a resistance board weir was used to collect abundance, run timing, and biological data from salmon returning to the East Fork Andreafsky River, a tributary to the lower Yukon River. A total of 200,981 chum *Oncorhynchus keta*, 7,801 chinook *O. tshawytscha*, 316,530 pink *O. gorbuscha*, 33 sockeye *O. nerka*, and 7 coho *O. kisutch* salmon were counted through the weir. A substantial proportion of the chum salmon return was not censused because weir installation was delayed due to high water. Picket spacing was wide enough for pink salmon to escape upstream undetected. Peak weekly passage occurred: July 3-9 for chum; July 10-16 for chinook; July 17-23 for pink; and July 24-30 for sockeye salmon. Coho salmon began passing the weir three days prior to removal.

Sex composition of chum and chinook salmon shifted from predominately males to predominately females as the runs progressed. The sampled escapement of female chum and chinook salmon was estimated to be 53 and 29%, respectively. An estimated 56% of the sampled chum salmon escapement were age 0.3, and 42% were age 0.4. Based on East Fork weir escapement data and lower Yukon River sample data, a portion of the chum salmon return, consisting primarily of males and age 0.4 fish, escaped past the study site prior to weir installation. Female chinook salmon were predominately age 1.4 and males were predominantly age 1.3.

Three Arctic grayling *Thymallus arcticus*, 12 northern pike *Esox lucius*, 133 Dolly Varden *Salvelinus malma*, and 3,811 whitefish *Prosopium cylindraceum* and *Coregonus* spp. were counted through the weir. Only larger sized resident species are represented because of picket spacing.

Introduction

The Andreafsky River is one of several lower Yukon River tributaries on the Yukon Delta National Wildlife Refuge (Refuge). The main stem Andreafsky River and its primary tributary, the East Fork, provide important spawning and rearing habitat for chum *Oncorhynchus keta*, chinook *O. tshawytscha*, pink *O. gorbuscha*, sockeye *O. nerka*, and coho *O. kisutch* salmon (USFWS 1991). It supports the largest return of pink salmon in the Yukon River drainage and typically ranks second to the Anvik River in early run chum (summer chum) salmon escapement and second to the Salcha River in chinook salmon escapement (Sandone 1989). Andreafsky River salmon also contribute to a large subsistence fishery and pass through two commercial fishery districts between the Yukon and Andreafsky River mouths (Bergstrom et al. 1992; Schultz et al. 1994).

Adequate escapements to individual tributaries and main stem spawning areas are required to maintain genetic diversity and sustainable harvests, but management is complicated by the mixed stock nature of the Yukon River fishery. Managers attempt to distribute catch through time to avoid over-harvesting individual stocks as each may have a characteristic migratory timing (Mundy 1982). Stocks or species returning in low numbers or early and late portions of runs may be over-harvested incidentally during intensive harvesting of abundant stocks. Data are lacking on many of these individual stocks in the Yukon River drainage and are needed for more precise management.

Summer chum and chinook salmon abundances in the Andreafsky and other tributary rivers have been estimated on a limited basis by the Alaska Department of Fish and Game (Department) using aerial index surveys (Bergstrom et al. 1992). These surveys are usually conducted after salmon are on the spawning grounds thus too late for making management decisions that affect escapement. Weather delays and poor visibility also make some aerial index surveys of questionable value. Even during optimal conditions these surveys are a relative index of abundance and tend to underestimate escapement (Bergstrom et al. 1992). In addition, age, sex, and size data cannot be collected using aerial index surveys.

In an effort to collect more accurate, timely, and complete escapement information than can be obtained by aerial index surveys, sonar was used to monitor summer chum salmon returns in the East Fork from 1981 to 1984 (Sandone 1989). The East Fork was chosen over the main stem because of the following: (1) sonar could be installed in the lower river because of favorable water depth and stream bottom conditions; (2) aerial index surveys previous to 1986 (Appendix 1) indicated that summer chum salmon were more abundant in the East Fork during most years; and (3) the East Fork received less recreational use than the main stem. However, the accuracy of escapement estimates was affected by large pink salmon returns in 1982 and 1984, and high water prevented proper transducer deployment in 1985 (Buklis 1983, 1984, 1985; Sandone 1989). In response to the difficulty of using sonar in the

East Fork, counting towers were used from 1986 to 1988. Favorable water conditions permitted extrapolation of summer chum and chinook salmon escapements from visual tower counts. However, since 1988, only aerial index surveys have been conducted.

Chum salmon returns to the Yukon River in 1993 were very poor, prompting closure of both the commercial and subsistence fisheries (ADFG 1994). Summer chum salmon returns have shown a general decrease in productivity since 1989 and stocks returning to the East Fork have been below the aerial index escapement objective of 109,000 fish (Appendix 1) since 1979 (Schultz et al. 1994). In 1993, the aerial escapement index was only 10,935 summer chum salmon based on an incomplete survey. This is considerably below aerial index estimates recorded in the 1970's that were as high as 223,485 fish, or sonar and tower counts conducted between 1981 and 1988 that ranged from 45,221 to 181,352 chum salmon.

During 1993, chinook salmon escapement objectives were achieved for all streams in the lower Yukon River drainage (Menard 1995). Chinook salmon returning to the East Fork have typically exceeded the aerial index escapement objective of 1,500 fish (Appendix 1) since 1984 (Schultz et al. 1994). In 1993, the aerial escapement index was 5,855 chinook salmon. This is substantially above historical aerial index and tower count estimates that ranged from 274 to 2,503 fish between 1961 and 1992.

The Alaska National Interest Lands Conservation Act (ANILCA) mandates that salmon populations and their habitats be conserved within the Refuge, international treaty obligations be fulfilled, and subsistence opportunities for local residents be provided. Salmon escapement studies for lower Yukon River tributaries on the Refuge and the endeavor to fulfill obligations included in the U.S./Canada Yukon River Interim Agreement are ranked as priorities in the Refuge Fishery Management Plan by the U.S. Fish and Wildlife Service (Service) and the Department (USFWS 1991). ANILCA mandates, however, may not be met without conservative management practices since reliable data on Refuge originating stocks are not available.

In 1994, the Service initiated a five-year study in the East Fork to: (1) enumerate adult salmon through a weir 45 river kilometers (rkm) upstream from the Yukon River; (2) describe run timing of summer chum, chinook, and pink salmon returns; (3) estimate the age, sex, and length composition of adult chum and chinook salmon populations; and (4) identify and count other fish species passing through the weir.

Study Area

The Andreafsky River is located in the lower Yukon River drainage in western Alaska (Figure 1). The regional climate is subarctic with extreme temperatures reaching 28.9°C and -42.2°C in St. Marys, Alaska (Leslie 1989). Mean July high and February low temperatures between 1967 and 1983 were 17.6°C and -18.2°C. Average yearly precipitation was approximately 48 cm of rain and 189 cm of snow. River ice break-up typically occurs in May or early June and the river usually begins to freeze in late October (USFWS 1991). Maximum discharge is most often reached following break-up, and sporadic high discharge periods are generated by heavy rains that are prevalent between late July and early September.

Draining a watershed of 5,450 km^2, the Andreafsky River is one of the three largest Yukon River tributaries within Refuge boundaries (USFWS 1991). The main stem and its largest tributary, the East Fork, parallel each other in a southwesterly direction for over 200 rkm before converging. The main stem continues for another 7 rkm before discharging into the Yukon River approximately 160 rkm from the Bering Sea. Flowing through the Andreafsky Wilderness for most of their length, the East Fork and Andreafsky River main stem are designated as wild rivers in the National Wild and Scenic River System.

The East Fork watershed originates in the Nulato Hills at approximately 700 m elevation and drains an area of about 1,950 km^2. The river cuts through alpine tundra at an average gradient of 7.6 m per km for 48 rkm. It then flows through a forested river valley bordered by hills that rarely exceed 400 m elevation. Willow, spruce, alder, and birch dominate the riparian zone and much of the hillsides. Dropping at an average rate of 1.4 m per km, this 130-rkm long section is characterized by glides and riffles flowing over gravel and rubble substrate. The East Fork widens in the lowermost 38 rkm and meanders through a wet lowland valley interspersed with forest and tundra and bordered by hills that are typically less than 230 m elevation. A gradient of 0.14 m per km and smaller substrate particles allow an abundance of aquatic grasses to grow in the lower stream channel. Water fluctuations in the Yukon River also have a substantial affect on the stage height in this section of the East Fork.

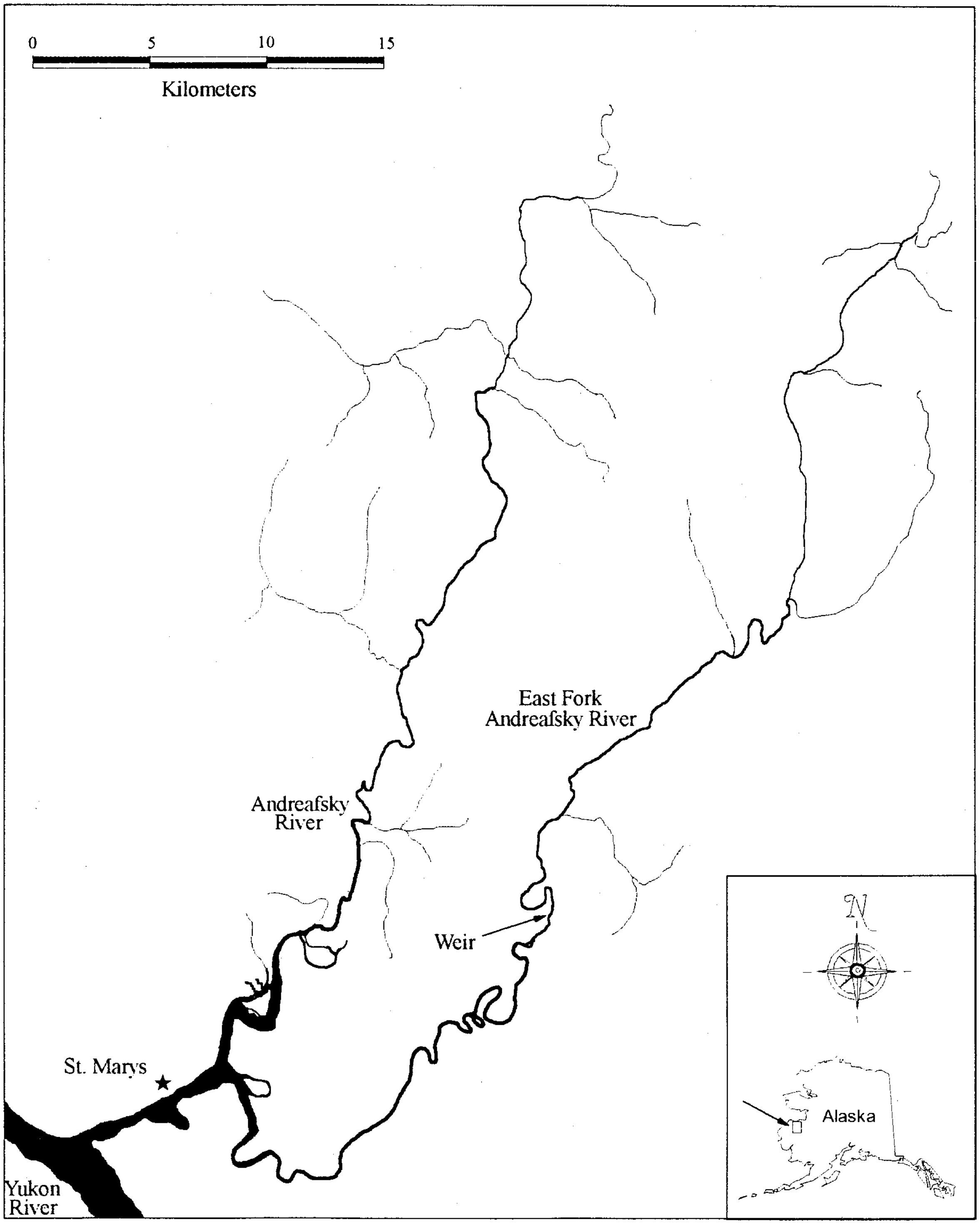

FIGURE 1.–Weir location in the East Fork Andreafsky River, 1994.

Methods

Weir Operation

A resistance board weir (Tobin 1994) spanning 85 meters of river was installed in the East Fork approximately 45 rkm upstream from the Yukon River and 27 air km NE (62°08'N, 162°48'W) from St. Marys, Alaska (Figure 1). This location is approximately 300 m upstream of the sonar and counting tower site described by Sandone (1989). The weir design described by Tobin (1994) was modified to improve performance at high flows, durability, and efficiency of fish passage. The modular live trap with aluminum structural components was designed to withstand debris loading and impact from drifting trees (Figure 2). A more durable and versatile passing chute was constructed by creating a 57 cm x 55 cm framed opening at the upstream end of a weir panel. Fish passed through an open-ended rectangular tube connecting the trap and the passing chute. Gaps between weir panel pickets were variable (3.5 cm and 4.8 cm), because new and recycled panels were used. The panels with wider picket intervals were designed to remain functional during higher flows and allow independent passage of pink salmon between pickets. A 7.6 cm wide x 1.2 m x 6 mm polyethylene plastic stringer was bolted to existing chain stay and resistance board stringers of all the weir panels (Figure 2, inset) to reduce breakage and slippage of these components. Five panels were also modified so that a picket could be partially removed to create a 13-cm wide x 70-cm long opening at the upstream end of each panel through which fish could pass. These fish passage panels were placed intermittently across the weir so that fish could be passed at various locations or simultaneously at several locations depending on fish behavior and migrational surges.

A staff gauge was installed downstream of the weir to gather daily water level data. Stream discharge was estimated using the method described by Hamilton and Bergersen (1984) using a Marsh-McBirney® (Model 201-D) flow meter and top setting wading rod. Water temperatures were collected once daily between 0630 and 0930 hours.

All fish were counted by species as they passed through a live trap or gaps created by partially removed pickets on modified fish passage panels. Salmon and resident fish that did not pass through these areas, but escaped upstream between pickets were not counted. Fish were passed and counted intermittently between 0001 hours and midnight. The duration of each counting session varied depending on the

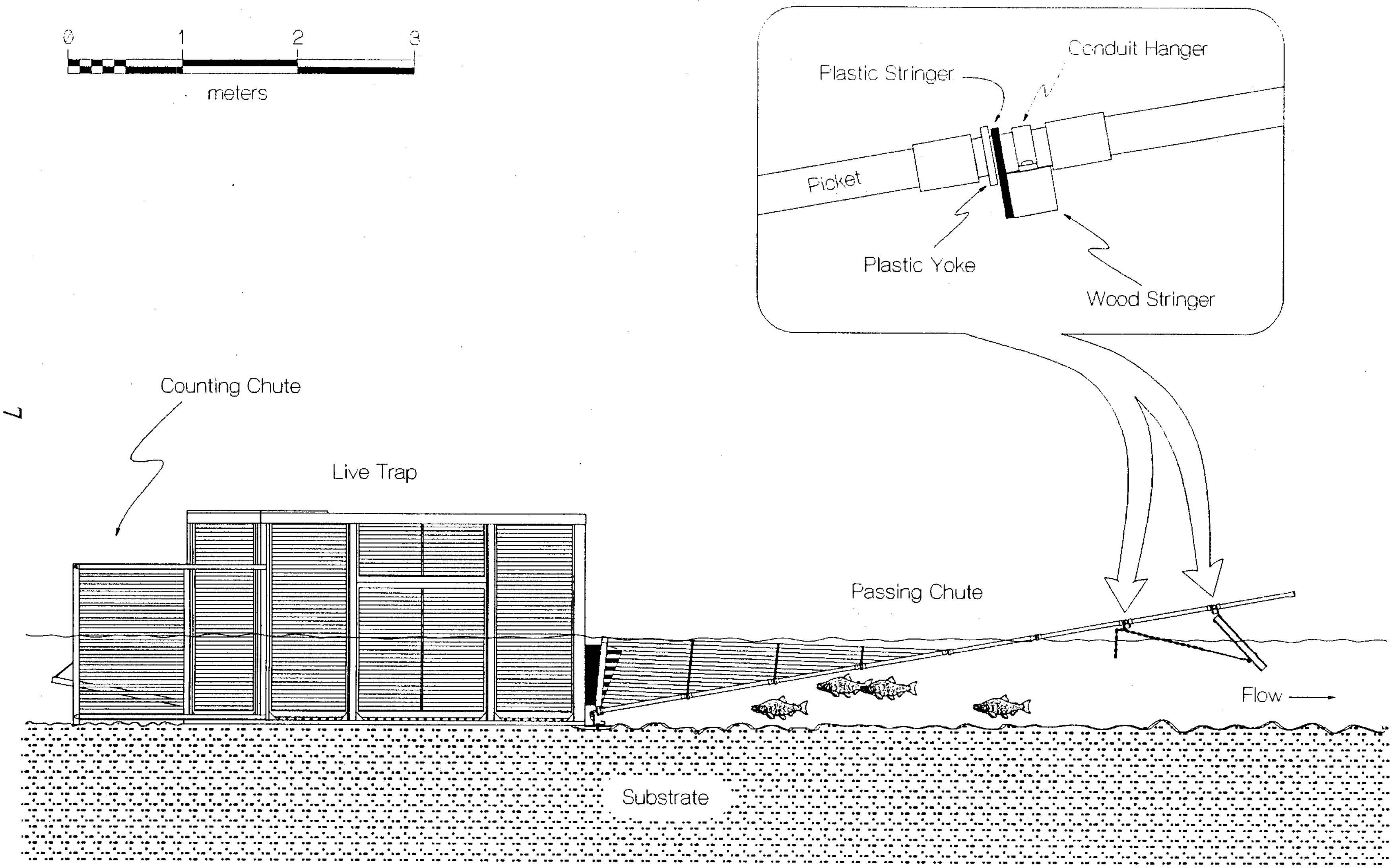

FIGURE 2.—Lateral view of the live trap and passing chute. Inset detail shows the modified stringer design.

intensity of fish passage through the weir and was recorded to the nearest 0.25 h for each station.

The weir was inspected for holes and cleaned daily. Snorkeling was used to check weir integrity and substrate conditions. Cleaning consisted of raking debris from the upstream surface of the weir or walking across each panel until it was partially submerged allowing the current to wash accumulations downstream.

Biological Data

Sampling consisted of determining length and sex, collecting scales, and then releasing the fish upstream of the weir. Salmon were measured to the nearest 5 mm mid-eye to fork length. Sex was determined using external characteristics. Scales were removed from the preferred area for age determination (Koo 1962; Mosher 1968). One scale was collected from each chum salmon and 4 scales were collected from each chinook salmon. Scale impressions were made on cellulose acetate cards using a heated scale press and examined with a microfiche reader. All salmon were aged by a Department biologist and reported according to the European Method (Koo 1962).

Sample weeks or strata began on Sunday and ended the following Saturday. However, partial weeks of weir operation shortened the first and last strata. Sampling commenced at the start of each stratum, and an effort was made to obtain a weekly quota of 160 chum and 140 chinook salmon in as short a period (1-3 d) as possible to approximate a pulse or snapshot sample (Geiger et al. 1990). All fish within the trap were sampled to prevent bias.

Mean lengths of males and females by age were compared using a two-tailed *t* test at $\alpha=0.05$ (Zar 1984). Age and sex composition were estimated using a stratified sampling design (Cochran 1977). Chi-square contingency table analysis was used to test for differences in age composition between the sexes. Because the standard test only applies to data collected under simple random sampling, adjustments were made to the test statistic, following Rao and Thomas (1989), to account for the impact of our stratified sampling design on the results. The X^2 statistic, hereafter referred to as $X^2(\hat{\delta}.)$, was divided by the mean generalized design effect, $\hat{\delta}.$, as a first-order correction to the standard test (Rao and Thomas 1989). Estimated design effects for the cells and marginals are presented in the results. Age composition and associated variances for weekly strata were calculated as:

$$\hat{A}_h = N_h \, p_h; \tag{1}$$

$$\hat{V}\,[\hat{A}_h] = N_h^2 \left(\frac{p_h(1-p_h)}{n_h-1} \right); \tag{2}$$

where:

$\hat{A}_h$ = estimated escapement for a species of a given age and sex during stratum h;
N_h = escapement for a species during stratum h;
p_h = proportion of the sample in stratum h of a given age and sex; and,
n_h = total number of a species in the sample for stratum h.

Abundance estimates and their variances for each stratum were summed to obtain age and sex composition estimates for combined strata as follows:

$$\hat{A}_{st} = \sum \hat{A}_h; \tag{3}$$

$$\hat{V}\,[\hat{A}_{st}] = \sum \hat{V}(\hat{A}_h); \tag{4}$$

where:

$\hat{A}_{st}$ = estimated escapement for a species of given age and sex for combined strata.

Results

Weir Operation

The weir was operated from June 29 to August 1, 1994. High water, resulting from late river ice break-up, delayed weir installation for two weeks. The weir remained functional throughout the operational period and was never submerged. A stream discharge of 32.3 m^3/s was measured 15 m upstream of the weir on July 17 (Appendix 2). On this date, the staff gauge indicated a stage height of 68 cm. The average and maximum water depths across the channel at this level were 68 cm and 122 cm. Water velocity averaged 0.52 m/s across the channel and reached 0.73 m/s at the thalweg. Moderate stage heights averaging 69 cm persisted throughout the operational period of the weir with minimum and maximum levels reaching 57 cm and 84 cm. Water temperatures averaged 12°C from July 2 to August 1 (Appendix 2). Minimum and maximum temperatures reached 9°C and 15°C.

Biological Data

Five species of Pacific salmon, including 200,981 chum, 7,801 chinook, 316,530 pink, 33 sockeye, and 7 coho salmon, were counted upstream through the weir (Appendix 3). Other species counted through the weir include 3 Arctic grayling *Thymallus arcticus*, 12 northern pike *Esox lucius*, 133 Dolly Varden *Salvelinus malma*, and 3,811 whitefish *Prosopium cylindraceum* and *Coregonus* spp. (Appendix 3).

Chum salmon.–Chum salmon were observed in the river approximately nine days prior to the first day of counting and passed through the weir from June 29 to August 1. On June 30, the first full day of operation, 19,254 chum salmon were counted through the weir. Peak passage (N=71,550) occurred the week of July 3-9; however, 35,138 chum salmon were counted the previous week during which the weir was operated for slightly more than three days (Figure 3; Appendix 3). Fifty percent of the chum salmon counted had passed the weir by July 8 (Figure 4; Appendix 4), and the counts declined to less than 500 fish per day prior to weir removal.

Three age groups were identified from 733 chum salmon sampled from the weir escapement between July 3 and August 1 (Table 1; Appendix 5). During this period, 165,843 chum salmon were passed through the weir. Males composed an estimated 47% of this escapement and predominated only during the first sample week (Figure 4; Appendix 5). Age 0.3 chum salmon were most abundant (56%) followed by age 0.4 fish (42%). Age 0.3 chum salmon were also most abundant during all sample weeks except the first, which consisted primarily of age 0.4 fish. Age composition did not differ between sexes ($X^2(\hat{\delta}.)=2.32$, df=2, P=0.31). The mean length of sampled males was greater than that of sampled females of all age groups (two-tailed t test: age 0.3, t=13.4, df=504, P<0.001; age 0.4, t=10.0, df=217, P<0.001; age 0.5, t=2.7, df=6, P=0.035)(Table 1).

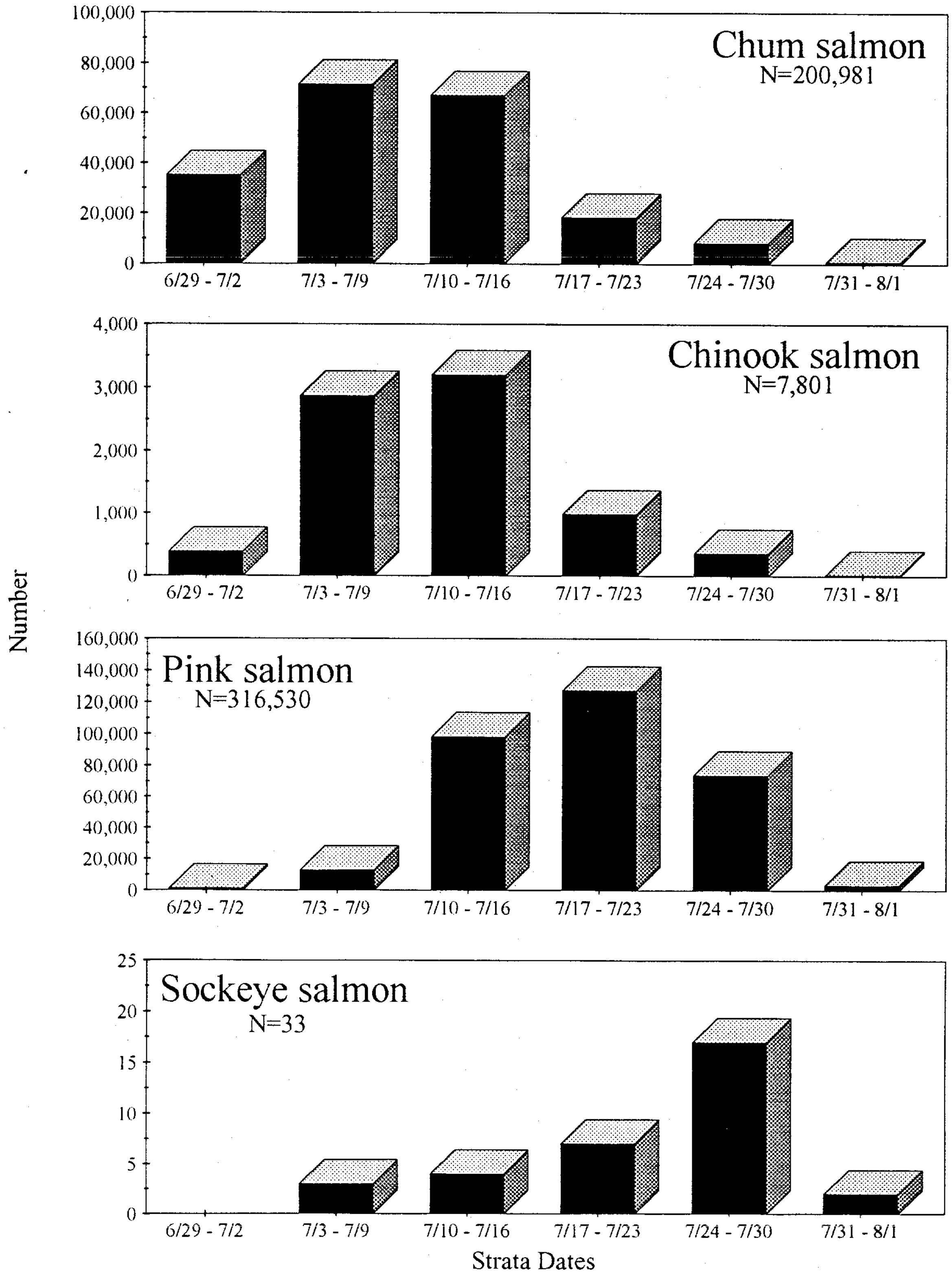

FIGURE 3.–Salmon escapement through the East Fork Andreafsky River weir, 1994. Note that the first and last strata are incomplete weeks.

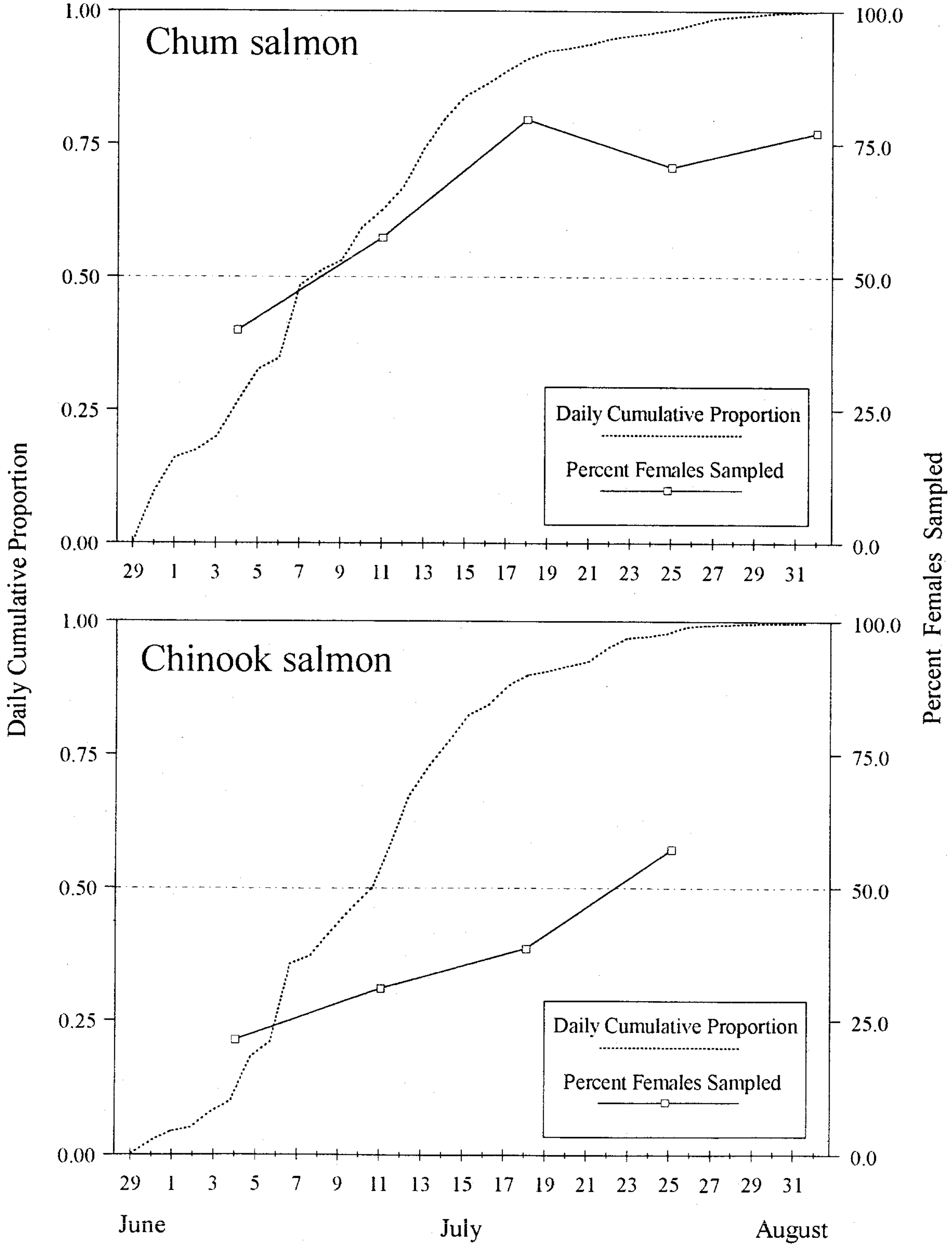

FIGURE 4.–Cumulative daily proportion of chum and chinook salmon escapement and sex composition of sampled fish at the East Fork Andreafsky River weir, 1994.

TABLE 1.–Length, age, and sex composition of chum salmon sampled at the East Fork Andreafsky River weir, 1994.

		Mid-Eye to Fork Length (mm)		
Age	N	Mean	SE	Range
		Female		
0.3	352	512	1.4	430-585
0.4	123	528	2.3	475-600
0.5	3	543	15.9	525-575
Total	478	516	1.3	430-600
		Male		
0.3	154	549	2.6	480-620
0.4	96	568	3.4	480-695
0.5	5	589	9.1	575-620
Total	255	557	2.1	480-695

Chinook salmon.–Chinook salmon passed through the weir from June 29 to August 1. On June 30, the first full day of operation, 188 chinook salmon were counted upstream. Peak passage (N=3,197) occurred the week of July 10-16 (Figure 3; Appendix 3), and 50% of the chinook salmon counted had passed the weir by July 11 (Figure 4; Appendix 4). Weekly chinook salmon escapement followed a downward trend after the run peaked and declined to less than 20 fish per day prior to weir removal.

Six age groups were identified from 440 chinook salmon sampled from the weir escapement between July 3 and July 30 (Table 2; Appendix 6). During this period, 7,406 chinook salmon were passed through the weir. Females composed an estimated 29% of this escapement and predominated only during the last sample week (Figure 4; Appendix 6). Age 1.3 chinook salmon were most abundant (60%)

followed by age 1.4 fish (29%). Age 1.3 chinook salmon were also most abundant during all sample weeks except the last, which consisted primarily of age 1.4 fish. Age composition differed between sexes ($X^2(\hat{\delta}.) = 100.76$, df=3, $P<0.0001$). Sixty-eight percent of females were age 1.4, and 76% of males were age 1.3. The mean length of sampled females was greater than that of sampled males in corresponding age groups (two-tailed t test: age 1.3, $t=5.4$, df=230, $P<0.001$; age 1.4, $t=4.4$, df=150, $P<0.001$)(Table 2).

TABLE 2.–Length, age, and sex composition of chinook salmon sampled at the East Fork Andreafsky River weir, 1994.

		Mid-Eye to Fork Length (mm)		
Age	N	Mean	SE	Range
		Female		
1.3	33	767	8.9	645-850
1.4	103	833	4.8	695-965
1.5	19	866	7.5	795-915
1.6	1	630	-	-
Total	156	823	4.6	645-965
		Male		
1.2	35	550	9.9	445-850
1.3	199	714	3.7	575-860
2.2	1	570	-	-
1.4	49	795	7.5	690-930
Total	284	707	5.1	445-930

Pink salmon.–Pink salmon were observed in the river approximately four days prior to the first day of counting and passed through the weir from June 29 to August 1.

On June 30, the first full day of operation, 451 pink salmon were counted through the weir. Peak passage ($N = 127,172$) occurred the week of July 17-23 (Figure 3; Appendix 3), and 50% of the pink salmon counted had passed the weir by July 18 (Figure 5; Appendix 4). Weekly pink salmon escapement followed a downward trend after the run peaked and declined to less than 3,000 fish per day prior to weir removal.

Sockeye salmon.–Sockeye salmon ($N = 33$) passed through the weir from July 7 to August 1. Peak passage ($N = 17$) occurred the week of July 24-30 (Figure 3; Appendix 3), and 50% of the sockeye salmon had passed the weir by July 26 (Figure 5).

Coho salmon.–Coho salmon ($N = 7$) began passing through the weir on July 30.

Discussion

Weir Operation

Weir modifications improved durability and fish passage. Moderate flows prevented evaluation of live trap and passing chute durability under debris loads; however, these components were more stable and easier to install than those described by Tobin (1994). Fish also located the passing chute and entered the live trap more readily because the chute did not extend beneath the horizontal plane of the weir panels. Breakage and slippage of the chain stay and resistance board stringers was eliminated with the modified composite stringers. The fish passage rate increased when fish were counted simultaneously through the counting chute and modified panels. Most fish, except for large chinook salmon, swam through the gaps in these panels without difficulty. Panels with wide picket intervals allowed pink salmon to swim upstream between the pickets and effectively blocked passage of other salmon species. Use of these panels appeared to reduce congestion of pink salmon downstream of the weir during migrational pulses.

Biological Data

Weekly escapement trends and observations of chum salmon in the river prior to weir installation indicate that a substantial proportion of this run was not censused. A presumably large number of pink salmon also passed upstream between weir

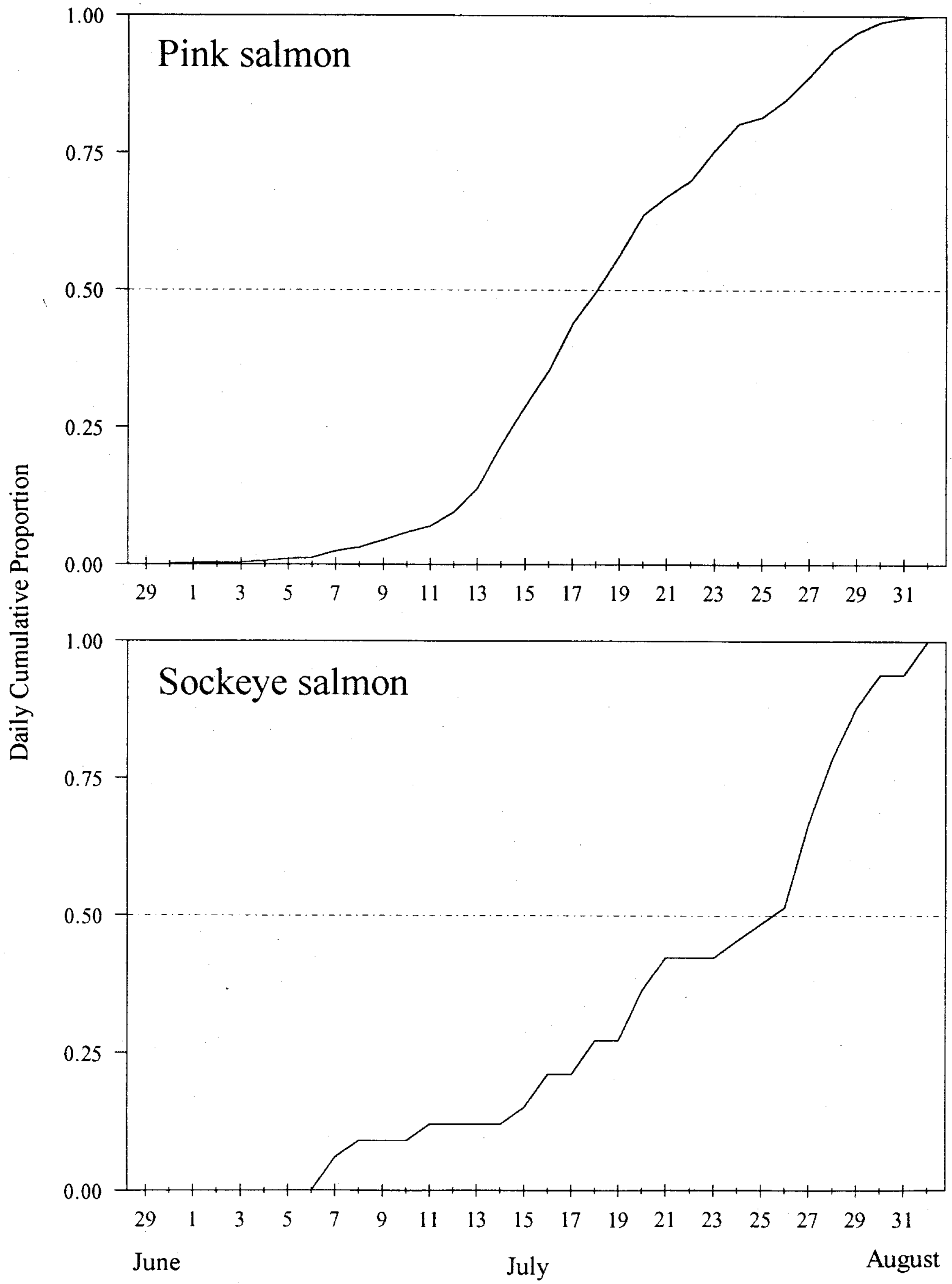

FIGURE 5.–Cumulative daily proportion of pink and sockeye salmon escapement through the East Fork Andreafsky River weir, 1994.

pickets, and a small proportion of the run was observed spawning downstream of the weir. Consequentially, escapement totals are conservative for these species and sample data are biased for chum salmon. Picket spacing also allowed smaller sized resident fish to pass through the weir undetected; therefore, these fish are not represented in resident species counts.

Chum salmon.–The weir escapement trend (Figure 3) indicates that run timing in the East Fork during 1994 resembled that in 1988 (Sandone 1989). In 1988, migrating chum salmon were present in the river from mid-June through July, and peak passage occurred near the end of June. Approximately 33% of the chum salmon counted from June 21 to July 25, 1988, had passed the counting tower by June 29, which is the date counting commenced in 1994. However, commercial fishery openings in the lower Yukon River may have reduced the passage rate of chum salmon through the weir during early July causing a false peak near the end of June, 1994. During 1986 and 1987, run peaks occurred near mid-July (Buklis 1986, 1987). Chum salmon were not observed at the tower site in June 1986, and only three chum salmon were counted prior to July 4, 1987.

Age and sex composition data may suggest a lower percentage of age 0.4 chum salmon and a higher percentage of females than actually was present in the population because the first segment of the run is not represented in the sample. Lower Yukon River test and commercial fishery samples indicate that males and age 0.4 chum salmon were predominant early in the run (preliminary data from Department files 1994).

Chinook salmon.–Tower counts from 1986 to 1988 indicate that chinook salmon were present in low numbers in late June (Buklis 1986, 1987; Sandone 1989). Run timing in 1994 was similar to that from 1986 through 1988. The weir escapement trend in 1994 (Figure 3) indicates that the majority of the chinook salmon returned in July and were censused.

Pink salmon.–Pink salmon returns to the Yukon River drainage are historically strongest during even years (Bergstrom et al. 1992). The number of pink salmon counted through the weir (N=316,530) during 1994 is substantially higher than the 1986 and 1987 tower counts (N=94,808 and 579 respectively) and similar to the 1988 tower count (N=275,128). However, based on observations by weir crew-members, the number of pink salmon counted through the weir represents only a fraction of the actual return because pink salmon frequently passed upstream between weir pickets. On July 22, a reconnaissance trip was conducted by boat covering 70-80 km of river upstream of the weir. Pink salmon appeared to outnumber chum salmon by a factor of at least two, and the cumulative weir count for pink salmon on this date was only 1.1 times greater than chum salmon. This information indicates that the total number of pink salmon counted through the weir is a large underestimate of the actual number that returned to the East Fork. The weir counts for pink salmon are, at best, an indicator of run timing, and may be used as a future indicator of relative abundance if physical barriers such as picket spacing remain unchanged.

Sockeye salmon.–Large populations of sockeye salmon are absent in the Yukon River drainage (Bergstrom et al. 1992), and little is known about the population in the East Fork. Additional years of data are needed to determine the stability of the East Fork sockeye salmon returns.

Coho salmon.–Data pertaining to coho salmon populations in the East Fork are limited. Two aerial index surveys estimated coho salmon escapements to be 1,657 and 1,913 fish during 1981 and 1988, respectively (Appendix 1). Seven coho salmon were counted through the weir prior to its removal, but the run had not developed.

Recommendations

Based on the data in this report, the following is recommended:

1. Install the weir by mid-June and extend operation into September to obtain comprehensive escapement data for summer chum, chinook, pink, and coho salmon returns.

2. A more suitable location for the weir was discovered 2.4 rkm downstream from the 1994 site. Relocating the weir to this wider and shallower section of river would enhance weir performance during high water conditions that are common during late summer.

Acknowledgments

Special appreciation is extended to those people who contributed to this project: John Crye constructed many of the weir components that made this project a success; Ted Otis was invaluable during weir installation and responsible as crew leader for data collection and daily weir operation; Andrew Journey, Otis Lake, and Eric Janney staffed the weir for the season. Steve Klosiewski assisted with the statistical analyses.

A special thanks also to the entire Yukon Delta National Wildlife Refuge staff. Dave Stearns, Dennis Strom, John Morgart, Mike Jensen, Bob Winkleman, George Walters, Phillip Paniyak and many others deserve special mention for their assistance. We also appreciate the assistance of the Alaska Department of Fish and Game (Commercial Fish Division, Emmonak Office) and to Jim Menard for aging of salmon scale samples and assisting with weir site selection. Bering Sea Fishermen's Association also contributed to this project by arranging and subsidizing the transport of camp supplies to the weir site.

The success of this project was also dependant on support from the people of St. Marys, Alaska. Foremost, we thank Lawrence Mike and St. Marys Native Corporation for generously granting the use of their land for our study site. Appreciation is also extended to Bart Calgrove; MarkAir Cargo employees; Michael and Eric Paukin; Frank and Darlene Primeau; Jean Luc and Judy Sevessand; Jr. Thompson; Eric Weingarth; and many others provided assistance beyond our expectations.

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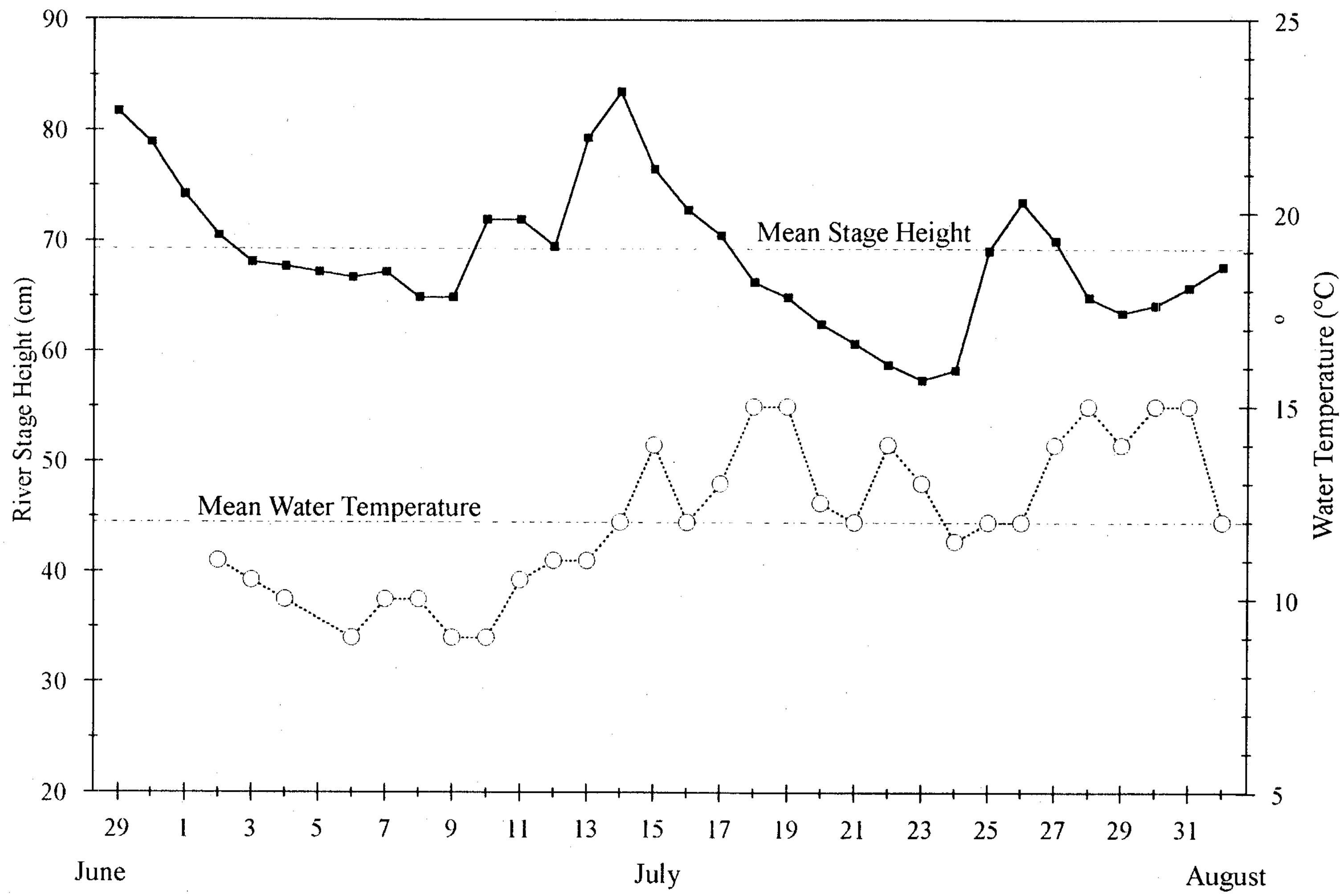
Appendix 1.-Chum, chinook, and coho salmon escapement counts for the Andreafsky River, 1961-1994. All data except weir counts are from Schultz et al. (1994).

	East Fork Andreafsky River					Main Stem Andreafsky River		
	Aerial Index Surveys			Sonar, Tower, or Weir		Aerial Index Surveys		
Year	Chinook Salmon	Chum Salmon	Coho Salmon	Chinook Salmon	Chum Salmon	Chinook Salmon	Chum Salmon	Coho Salmon
1961	1,003							
1962	675 *a*					762 *a*		
1963								
1964	867					705		
1965						344 *a*		
1966	361					303		
1967						276 *a*		
1968	380					383		
1969	274 *a*					231 *a*		
1970	665					574 *a*		
1971	1,904					1,682		
1972	798					582 *a*		
1973	825	10,149 *a*				788	51,835	
1974		3,215 *a*				285	33,578	
1975	993	223,485				301	235,954	
1976	818	105,347				643	118,420	
1977	2,008	112,722				1,499	63,120	
1978	2,487	127,050				1,062	57,321	
1979	1,180	66,471				1,134	43,391	
1980	958 *a*	36,823 *a*				1,500	114,759	
1981	2,146 *a*	81,555	1,657 *a*		147,312 *b*	231 *a*		
1982	1,274	7,501 *a*			181,352 *b*	851	7,267 *a*	
1983					110,608 *b*			
1984	1,573 *a*	95,200 *a*			70,125 *b*	1,993	238,565	
1985	1,617	66,146				2,248	52,750	
1986	1,954	83,931		1,530 *c*	167,614 *c*	3,158	99,373	
1987	1,608	6,687 *a*		2,011 *c*	45,221 *c*	3,281	35,535	
1988	1,020	43,056	1,913	1,339 *c*	68,937 *c*	1,448	45,432	830
1989	1,399	21,460 *a*				1,089		
1990	2,503	11,519 *a*				1,545	20,426 *a*	
1991	1,938	31,886				2,544	46,657	
1992	1,030 *a*	11,308 *a*				2,002 *a*	37,808 *a*	
1993	5,855	10,935 *a*				2,765	9,111 *a*	
1994	300 *ae*			7,801 *d*	200,981 *ad*	213 *ae*		
E.O.	>1,500	>109,000				>1,400	>116,000	

E.O. Interim escapement objective for aerial index surveys.
a Incomplete survey and/or poor survey timing or conditions resulting in minimal or inaccurate count.
b Sonar count
c Tower count
d Weir count
e Preliminary



Appendix 2.-River stage heights and water temperatures at the East Fork Andreafsky River weir, 1994.

Appendix 3.-Daily escapement and counting effort at the East Fork Andreafsky River weir, 1994.

Date	Hours of Counting	Chum Salmon	Chinook Salmon	Pink Salmon	Sockeye Salmon	Coho Salmon	Dolly Varden	Whitefish	Arctic Grayling	Northern Pike
				Stratum 1						
06/29	0.50	609	1	8	0	0	0	0	0	0
06/30	11.50	19,254	188	451	0	0	1	0	0	0
07/01	14.75	12,435	141	409	0	0	8	72	3	0
07/02	11.75	2,840	54	194	0	0	0	41	0	0
Total:	38.50	35,138	384	1,062	0	0	9	113	3	0
				Stratum 2						
07/03	11.25	4,973	222	305	0	0	3	18	0	1
07/04	12.00	13,321	156	780	0	0	22	47	0	1
07/05	13.75	12,552	651	1,027	0	0	1	60	0	0
07/06	11.00	4,043	225	772	0	0	0	37	0	1
07/07	15.75	27,527	1,156	4,026	2	0	3	146	0	1
07/08	9.25	5,251	108	1,736	1	0	1	103	0	0
07/09	8.50	3,883	351	4,263	0	0	89	82	0	0
Total:	81.50	71,550	2,869	12,909	3	0	119	493	0	4
				Stratum 3						
07/10	12.00	12,416	375	4,744	0	0	0	144	0	0
07/11	13.25	6,896	288	3,313	1	0	0	130	0	0
07/12	11.25	8,424	581	8,447	0	0	0	232	0	0
07/13	13.25	14,628	779	13,568	0	0	1	212	0	0
07/14	11.00	11,611	433	24,842	0	0	0	242	0	0
07/15	11.75	8,275	352	22,460	1	0	0	222	0	1
07/16	9.50	4,690	389	20,612	2	0	0	223	0	0
Total:	82.00	66,940	3,197	97,986	4	0	1	1,405	0	1
				Stratum 4						
07/17	9.50	4,886	144	27,053	0	0	2	170	0	0
07/18	11.25	4,532	285	18,277	2	0	0	133	0	0
07/19	10.50	2,977	161	20,792	0	0	0	142	0	0
07/20	13.25	1,091	53	23,511	3	0	0	158	0	1
07/21	10.75	1,351	66	10,872	2	0	0	95	0	1
07/22	10.25	2,228	62	8,975	0	0	0	75	0	0
07/23	10.50	1,320	209	17,692	0	0	1	119	0	0
Total:	76.00	18,385	980	127,172	7	0	3	892	0	2

(Continued)

Appendix 3.-(Continued)

Date	Hours of Counting	Chum Salmon	Chinook Salmon	Pink Salmon	Sockeye Salmon	Coho Salmon	Dolly Varden	Whitefish	Arctic Grayling	Northern Pike
					Stratum 5					
07/24	11.25	868	149	15,120	1	0	0	118	0	0
07/25	9.25	1,349	25	3,566	1	0	0	42	0	0
07/26	9.75	1,977	51	10,225	1	0	0	165	0	2
07/27	9.50	2,196	92	13,821	5	0	0	168	0	1
07/28	12.00	841	20	15,302	4	0	1	146	0	1
07/29	9.50	564	10	9,736	3	0	0	92	0	0
07/30	8.50	524	13	6,159	2	1	0	103	0	0
Total:	69.75	8,319	360	73,929	17	1	1	834	0	4
					Stratum 6					
07/31	8.00	410	10	2,476	0	0	0	62	0	1
08/1	4.00	239	1	996	2	6	0	12	0	0
Total:	12.00	649	11	3472	2	6	0	74	0	1
					All Strata					
Total:	359.75	200,981	7,801	316,530	33	7	133	3,811	3	12

Appendix 4.-Daily, daily cumulative, and daily cumulative proportion of salmon escapement through the East Fork Andreafsky River weir, 1994.

	Chum Salmon			Chinook Salmon			Pink Salmon		
Date	Daily Count	Cumulative Count	Cumulative Proportion	Daily Count	Cumulative Count	Cumulative Proportion	Daily Count	Cumulative Count	Cumulative Proportion
06/29	609	609	0.003	1	1	0.000	8	8	0.000
06/30	19,254	19,863	0.099	188	189	0.024	451	459	0.001
07/01	12,435	34,689	0.161	141	330	0.042	409	868	0.003
07/02	2,840	15,275	0.175	54	384	0.049	194	1,062	0.003
07/03	4,973	7,813	0.200	222	606	0.078	305	1,367	0.004
07/04	13,321	18,294	0.266	156	762	0.098	780	2,147	0.007
07/05	12,552	25,873	0.328	651	1,413	0.181	1,027	3,174	0.010
07/06	4,043	70,027	0.348	225	1,638	0.210	772	3,946	0.012
07/07	27,527	97,554	0.485	1,156	2,794	0.358	4,026	7,972	0.025
07/08	5,251	102,805	0.512	108	2,902	0.372	1,736	9,708	0.031
07/09	3,883	106,688	0.531	351	3,253	0.417	4,263	13,971	0.044
07/10	12,416	119,104	0.593	375	3,628	0.465	4,744	18,715	0.059
07/11	6,896	126,000	0.627	288	3,916	0.502	3,313	22,028	0.070
07/12	8,424	134,424	0.669	581	4,497	0.576	8,447	30,475	0.096
07/13	14,628	149,052	0.742	779	5,276	0.676	13,568	44,043	0.139
07/14	11,611	160,663	0.799	433	5,709	0.732	24,842	68,885	0.218
07/15	8,275	168,938	0.841	352	6,061	0.777	22,460	91,345	0.289
07/16	4,690	173,628	0.864	389	6,450	0.827	20,612	111,957	0.354
07/17	4,886	178,514	0.888	144	6,594	0.845	27,053	139,010	0.439
07/18	4,532	183,046	0.911	285	6,879	0.882	18,277	157,287	0.497
07/19	2,977	186,023	0.926	161	7,040	0.902	20,792	178,079	0.563
07/20	1,091	187,114	0.931	53	7,093	0.909	23,511	201,590	0.637
07/21	1,351	188,465	0.938	66	7,159	0.918	10,872	212,462	0.671
07/22	2,228	190,693	0.949	62	7,221	0.926	8,975	221,437	0.700
07/23	1,320	192,013	0.955	209	7,430	0.952	17,692	239,129	0.755
07/24	868	192,881	0.960	149	7,579	0.972	15,120	254,249	0.803
07/25	1,349	194,230	0.966	25	7,604	0.975	3,566	257,815	0.815
07/26	1,977	196,207	0.976	51	7,655	0.981	10,225	268,040	0.847
07/27	2,196	198,403	0.987	92	7,747	0.993	13,821	281,861	0.890
07/28	841	199,244	0.991	20	7,767	0.996	15,302	297,163	0.939
07/29	564	199,808	0.994	10	7,777	0.997	9,736	306,899	0.970
07/30	524	200,332	0.997	13	7,790	0.999	6,159	313,058	0.989
07/31	410	200,742	0.999	10	7,800	1.000	2,476	315,534	0.997
08/1	239	200,981	1.000	1	7,801	1.000	996	316,530	1.000

Appendix 5.-Estimated age and sex composition of weekly chum salmon escapements through the East Fork Andreafsky River weir, 1994, and estimated design effects of stratified sampling design.

		Brood Year and Age Group			
		1990	1989	1988	
		0.3	0.4	0.5	Total
Stratum 1: 6/29 - 7/02 Sampling Dates: No samples collected					
Stratum 2: 7/03 - 7/09 Sampling Dates: 7/03					
Female:	Number in Sample:	20	36	2	58
	Estimated % of Escapement:	13.8	24.8	1.4	40.0
	Estimated Escapement:	9,869	17,764	987	28,620
Male:	Number in Sample:	39	46	2	87
	Estimated % of Escapement:	26.9	31.7	1.4	60.0
	Estimated Escapement:	19,244	22,699	987	42,930
Total:	Number in Sample:	59	82	4	145
	Estimated % of Escapement:	40.7	56.6	2.8	100.0
	Estimated Escapement:	29,113	40,463	1,974	71,550
	Standard Error:	2,929	2,956	977	
Stratum 3: 7/10 - 7/16 Sampling Dates: 7/10					
Female:	Number in Sample:	55	25	1	81
	Estimated % of Escapement:	39.0	17.7	0.7	57.4
	Estimated Escapement:	26,111	11,869	475	38,455
Male:	Number in Sample:	34	24	2	60
	Estimated % of Escapement:	24.1	17.0	1.4	42.6
	Estimated Escapement:	16,142	11,394	950	28,485
Total:	Number in Sample:	89	49	3	141
	Estimated % of Escapement:	63.1	34.8	2.1	100.0
	Estimated Escapement:	42,253	23,263	1,424	66,940
	Standard Error:	2,730	2,694	816	
Stratum 4: 7/17 - 7/23 Sampling Dates: 7/18 - 7/19					
Female:	Number in Sample:	93	25	0	118
	Estimated % of Escapement:	62.8	16.9	0.0	79.7
	Estimated Escapement:	11,553	3,106	0	14,658
Male:	Number in Sample:	25	5	0	30
	Estimated % of Escapement:	16.9	3.4	0.0	20.3
	Estimated Escapement:	3,106	621	0	3,727
Total:	Number in Sample:	118	30	0	148
	Estimated % of Escapement:	79.7	20.3	0.0	100.0
	Estimated Escapement:	14,658	3,727	0	18,385
	Standard Error:	610	610	0	

(Continued)

Appendix 5.-(Continued).

		Brood Year and Age Group			
		1990	1989	1988	
		0.3	0.4	0.5	Total
Stratum 5: 7/24 - 7/30 Sampling Dates: 7/25					
Female:	Number in Sample:	87	19	0	106
	Estimated % of Escapement:	58.0	12.7	0.0	70.7
	Estimated Escapement:	4,825	1,054	0	5,879
Male:	Number in Sample:	34	10	0	44
	Estimated % of Escapement:	22.7	6.7	0.0	29.3
	Estimated Escapement:	1,886	555	0	2,440
Total:	Number in Sample:	121	29	0	150
	Estimated % of Escapement:	80.7	19.3	0.0	100.0
	Estimated Escapement:	6,711	1,608	0	8,319
	Standard Error:	269	269	0	
Stratum 6: 7/31 - 8/01 Sampling Dates: 8/01					
Female:	Number in Sample:	97	18	0	115
	Estimated % of Escapement:	65.1	12.1	0.0	77.2
	Estimated Escapement:	423	78	0	501
Male:	Number in Sample:	21	12	1	34
	Estimated % of Escapement:	14.1	8.1	0.7	22.8
	Estimated Escapement:	91	52	4	148
Total:	Number in Sample:	118	30	1	149
	Estimated % of Escapement:	79.2	20.1	0.7	100.0
	Estimated Escapement:	514	131	4	649
	Standard Error:	22	21	4	
Strata 2 - 6: 7/03 - 8/01 Sampling Dates: 7/03 - 8/01					
Female:	Number in Sample:	352	123	3	478
	% Females in Age Group:	59.9	38.4	1.7	100.0
	Estimated % of Escapement:	31.8	20.4	0.9	53.1
	Estimated Escapement:	52,781	33,871	1,462	88,113
	Estimated design effects	1.532	1.912	2.160	1.798
Male:	Number in Sample:	153	97	5	255
	% Males in Age Group:	52.1	45.4	2.5	100.0
	Estimated % of Escapement:	24.4	21.3	1.2	46.9
	Estimated Escapement:	40,469	35,321	1,941	77,730
	Estimated design effects	1.912	1.957	2.143	1.798
Total:	Number in Sample:	505	220	8	733
	Estimated % of Escapement:	56.2	41.7	2.1	100.0
	Estimated Escapement:	93,249	69,191	3,402	165,843 *
	Standard Error:	4,059	4,054	1,273	
	Estimated design effects	1.782	1.799	2.146	

* 35,138 fish that were counted through the weir during stratum 1 are not included in this total.

Appendix 6.-Estimated age and sex composition of weekly chinook salmon escapements through the East Fork Andreafsky River weir, 1994, and estimated design effects of stratified sampling design.

		Brood Year and Age Group						
		1990	1989		1988	1987	1986	
		1.2	1.3	2.2	1.4	1.5	1.6	Total
Stratum 1: 6/29 - 7/02								
Sampling Dates: No samples collected								
Stratum 2: 7/03 - 7/09								
Sampling Dates: 7/04 - 7/05								
Female:	Number in Sample:	0	2	0	5	0	0	7
	Estimated % of Escapement:	0.0	6.1	0.0	15.2	0.0	0.0	21.2
	Estimated Escapement:	0	174	0	435	0	0	609
Male:	Number in Sample:	3	21	0	2	0	0	26
	Estimated % of Escapement:	9.1	63.6	0.0	6.1	0.0	0.0	78.8
	Estimated Escapement:	261	1,826	0	174	0	0	2,260
Total:	Number in Sample:	3	23	0	7	0	0	33
	Estimated % of Escapement:	9.1	69.7	0.0	21.2	0.0	0.0	100.0
	Estimated Escapement:	261	2,000	0	609	0	0	2,869
	Standard Error:	146	233	0	207	0	0	
Stratum 3: 7/10 - 7/16								
Sampling Dates: 7/10 -7/16								
Female:	Number in Sample:	0	12	0	36	8	0	56
	Estimated % of Escapement:	0.0	6.6	0.0	19.8	4.4	0.0	30.8
	Estimated Escapement:	0	211	0	632	141	0	984
Male:	Number in Sample:	12	96	0	18	0	0	126
	Estimated % of Escapement:	6.6	52.7	0.0	9.9	0.0	0.0	69.2
	Estimated Escapement:	211	1,686	0	316	0	0	2,213
Total:	Number in Sample:	12	108	0	54	8	0	182
	Estimated % of Escapement:	6.6	59.3	0.0	29.7	4.4	0.0	100.0
	Estimated Escapement:	211	1,897	0	949	141	0	3,197
	Standard Error:	59	117	0	109	49	0	
Stratum 4: 7/17 - 7/23								
Sampling Dates: 7/18 - 7/22								
Female:	Number in Sample:	0	18	0	46	8	1	73
	Estimated % of Escapement:	0.0	9.5	0.0	24.2	4.2	0.5	38.4
	Estimated Escapement:	0	93	0	237	41	5	377
Male:	Number in Sample:	19	74	0	24	0	0	117
	Estimated % of Escapement:	10.0	38.9	0.0	12.6	0.0	0.0	61.6
	Estimated Escapement:	98	382	0	124	0	0	603
Total:	Number in Sample:	19	92	0	70	8	1	190
	Estimated % of Escapement:	10.0	48.4	0.0	36.8	4.2	0.5	100.0
	Estimated Escapement:	98	475	0	361	41	5	980
	Standard Error:	21	36	0	34	14	5	

(Continued)

Appendix 6.-(Continued).

		Brood Year and Age Group						
		1990	1989		1988	1987	1986	
		1.2	1.3	2.2	1.4	1.5	1.6	Total
Stratum 5: 7/24 - 7/30 Sampling Dates: 7/25 - 7/26								
Female:	Number in Sample:	0	1	0	16	3	0	20
	Estimated % of Escapement:	0.0	2.9	0.0	45.7	8.6	0.0	57.1
	Estimated Escapement:	0	10	0	165	31	0	206
Male:	Number in Sample:	1	8	1	5	0	0	15
	Estimated % of Escapement:	2.9	22.9	2.9	14.3	0.0	0.0	42.9
	Estimated Escapement:	10	82	10	51	0	0	154
Total:	Number in Sample:	1	9	1	21	3	0	35
	Estimated % of Escapement:	2.9	25.7	2.9	60.0	8.6	0.0	100.0
	Estimated Escapement:	10	93	10	216	31	0	360
	Standard Error:	10	27	10	30	17	0	
Stratum 6: 7/31 - 8/01 Sampling Dates: No samples collected								
Strata 2 - 5: 7/03 - 7/30 Sampling Dates: 7/04 - 7/26								
Female:	Number in Sample:	0	33	0	103	19	1	156
	% Females in Age Group:	0.0	22.4	0.0	67.6	9.8	0.2	100.0
	Estimated % of Escapement:	0.0	6.6	0.0	19.8	2.9	0.1	29.4
	Estimated Escapement:	0	488	0	1,469	213	5	2,175
	Estimated design effects	1.000	2.428 *		2.210	0.813 **		2.206
Male:	Number in Sample:	35	199	1	49	0	0	284
	% Males in Age Group:	11.1	76.0	0.2	12.7	0.0	0.0	100.0
	Estimated % of Escapement:	7.8	53.7	0.1	9.0	0.0	0.0	70.6
	Estimated Escapement:	580	3,976	10	665	0	0	5,231
	Estimated design effects	2.806	2.432 *		2.027	1.000 **		2.206
Total:	Number in Sample:	35	232	1	152	19	1	440
	Estimated % of Escapement:	7.8	60.3	0.1	28.8	2.9	0.1	100.0
	Estimated Escapement:	580	4,464	10	2,134	213	5	7,406 ***
	Standard Error	159	264	10	238	54	5	
	Estimated design effects	2.806	2.343 *		2.219	0.813 **		

* Age 1.3 and 2.2 fish combined into one group for contingency table analysis.

** Age 1.5 and 1.6 fish combined into one group for contingency table analysis.

*** 395 fish that were counted through the weir during strata that were not sampled are not included in this total.